An Economic Model of Distributed Generation

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- How to reconcile users' and Distros' incentives: A Coasian approach: Distro owns the PV panel
- Trade – off between incentives and market power: potential rents in passthrough $\rightarrow$ regulators must monitor
- Concluding remarks

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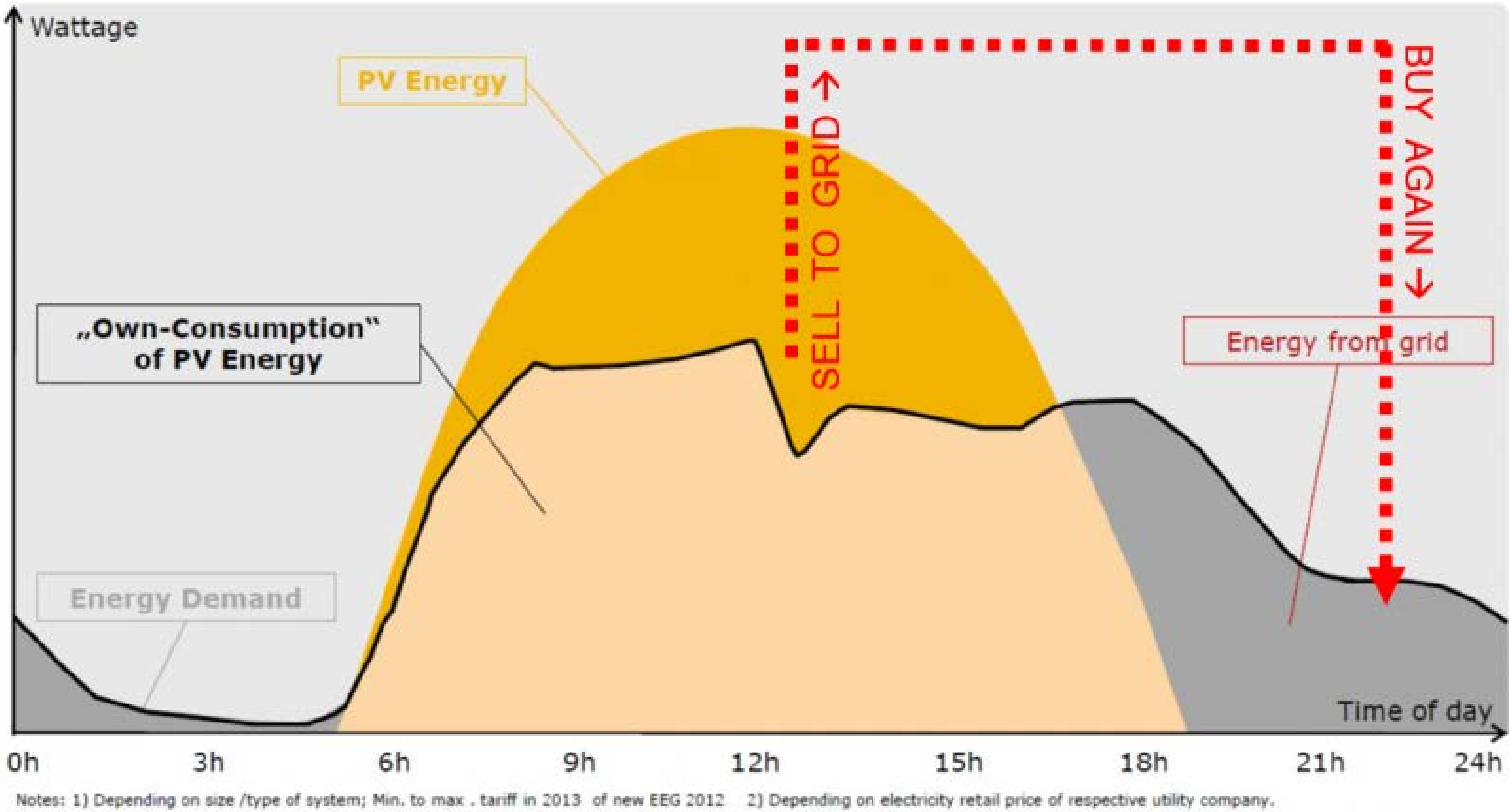
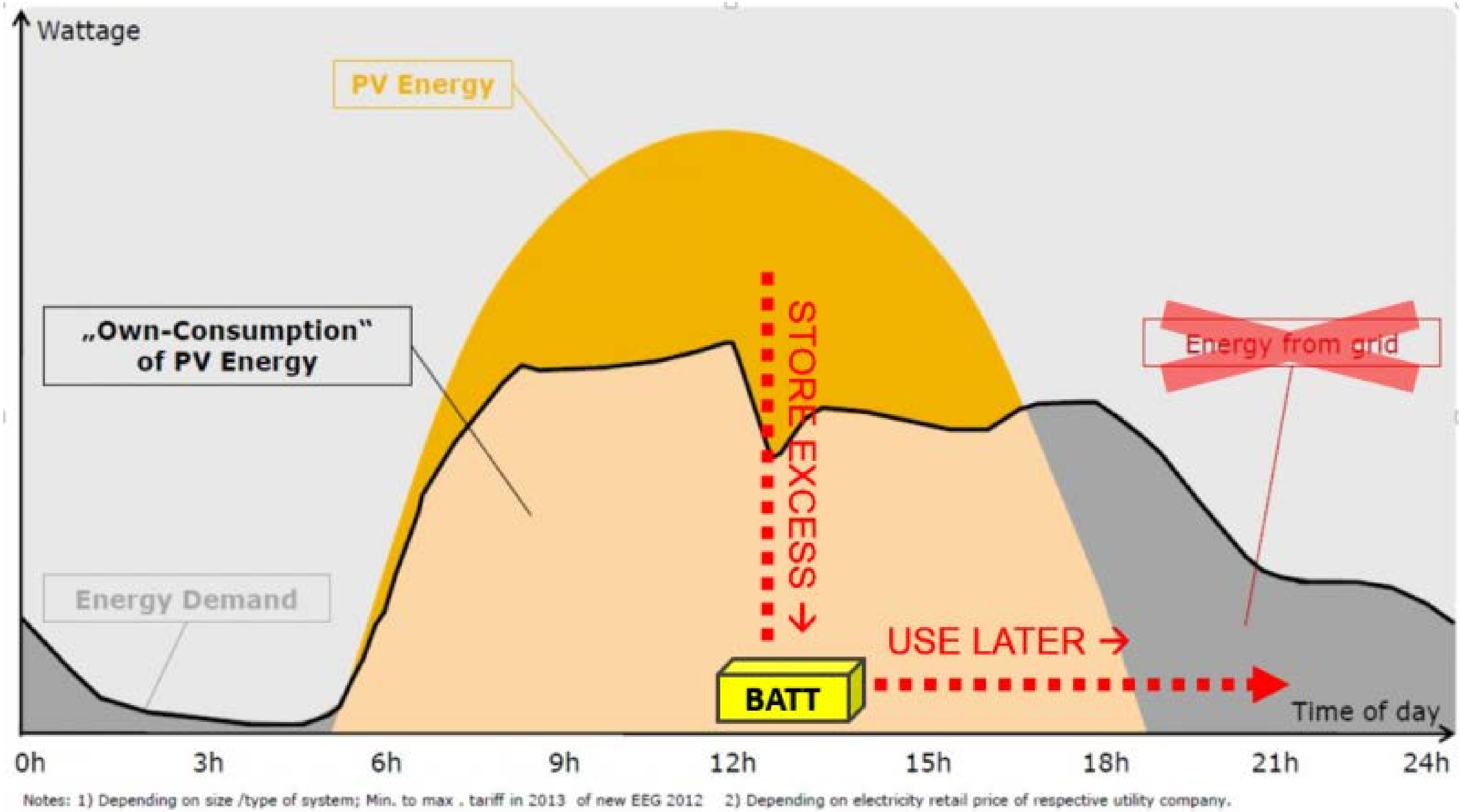
Argentina's DG Law 27.424 and its implementation

- 3 types of DG users:
  - Small (≤ 3KW), only T_1 users
  - Medium (3KW < K < 300KW) for MT and AT, T_1, T_2 T_3
  - Large (300KW < K < 2MW for MT and AT): T_3 and GUs
- Net Billing arrangement with bidirectional meter
- Capacity of DG equipment $\theta K \leq$ Installed capacity K, $\theta \leq 1$
- DG user will consume self generated electricity and inject eventual surpluses into the Distro's network
- DG user will collect (P_E + T) plus losses for each KWh injected

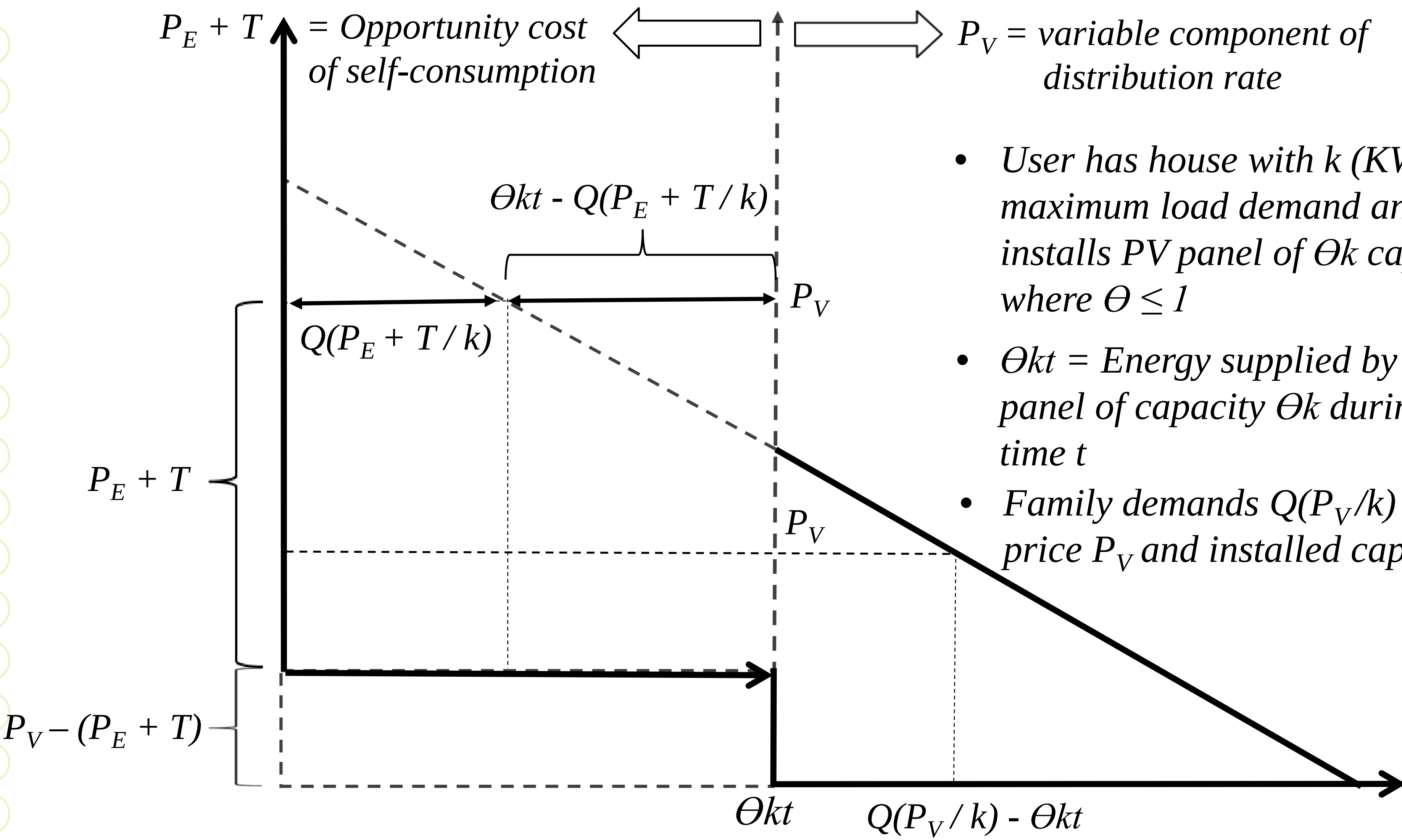
Argentina's DG model: Self – consume selling eventual surpluses to the grid



Argentina's DG model: not quite there yet…



Supply and Demand in a DG model



- *User has house with k (KW) of maximum load demand and installs PV panel of Θk capacity where $\Theta \leq 1$*
- *Θkt = Energy supplied by PV panel of capacity Θk during time t*
- *Family demands $Q(P_V/k)$ given price P_V and installed capacity k*

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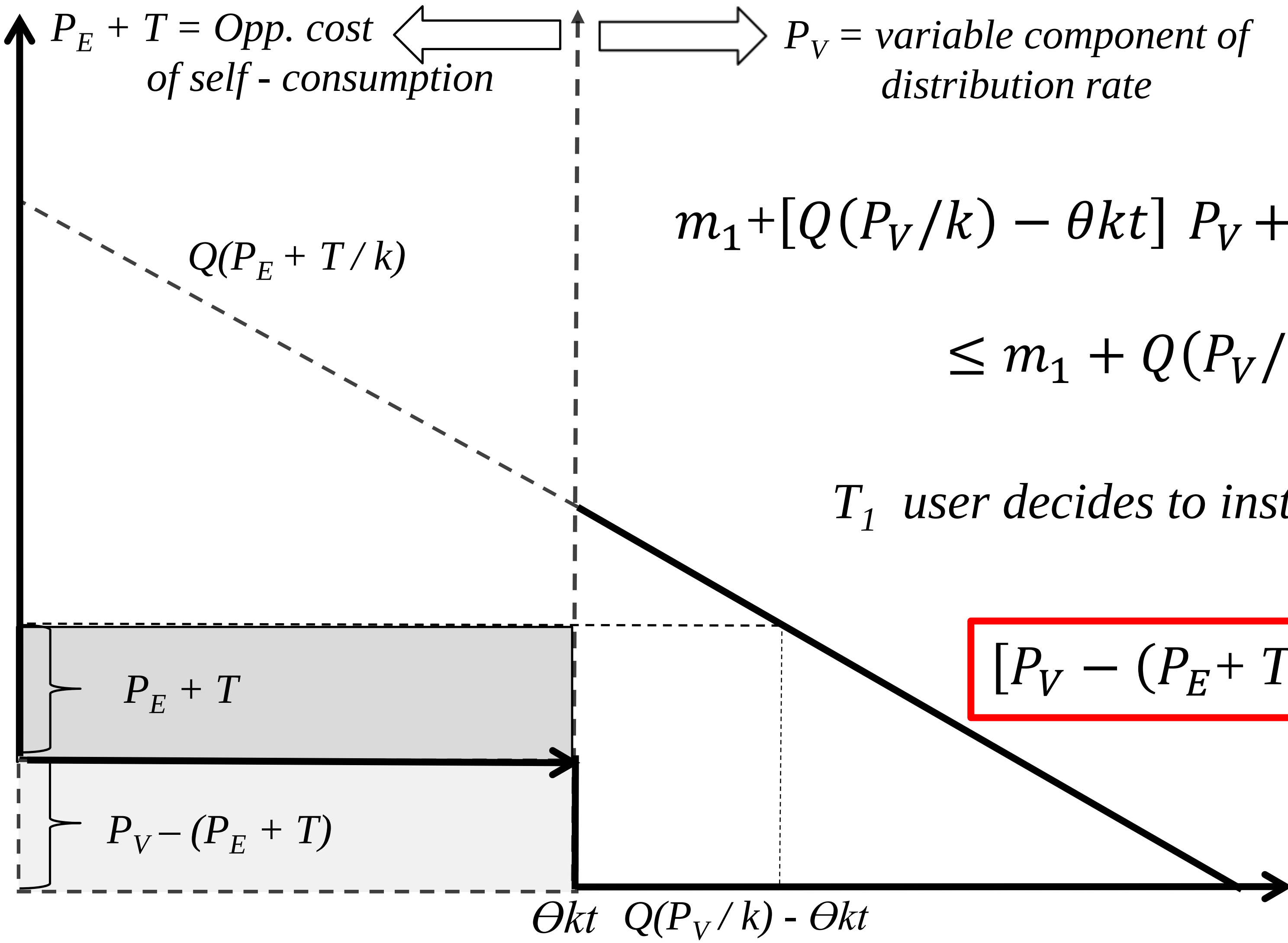
PV Panel Installation Decision by a T_1 User : *Host Ownership Model (HOM)*



$$m_1 + [Q(P_V/k) - \theta kt]\ P_V + \theta kt\ (P_E + T) + C$$

$$\leq m_1 + Q(P_V/k)P_V$$

T_1 user decides to install PV panel iff

$$\boxed{[P_V - (P_E + T)]\theta kt - C \geq 0}$$

PV Panel Installation Decision by a T_1 User : *More incentives to install PV panel if...*

$$[P_V - (P_E + T)]\theta kt - C \geq 0$$

High variable component of user tariff (i.e. high avoided cost)	*Low opportunity cost of self consumption*	*Low purchase, installation and O&M cost*

- The higher the ratio (PV/m) the more incentives to install (e.g. California PUC model) → problem "*Cost or Revenue Shifting*" → cross subsidies
- Fixed charge sunk (irrelevant) as longs as user does not change category between scenarios (not likely in AMBA)
- Fixed charge sunk as long as it does not force disconnection with storage

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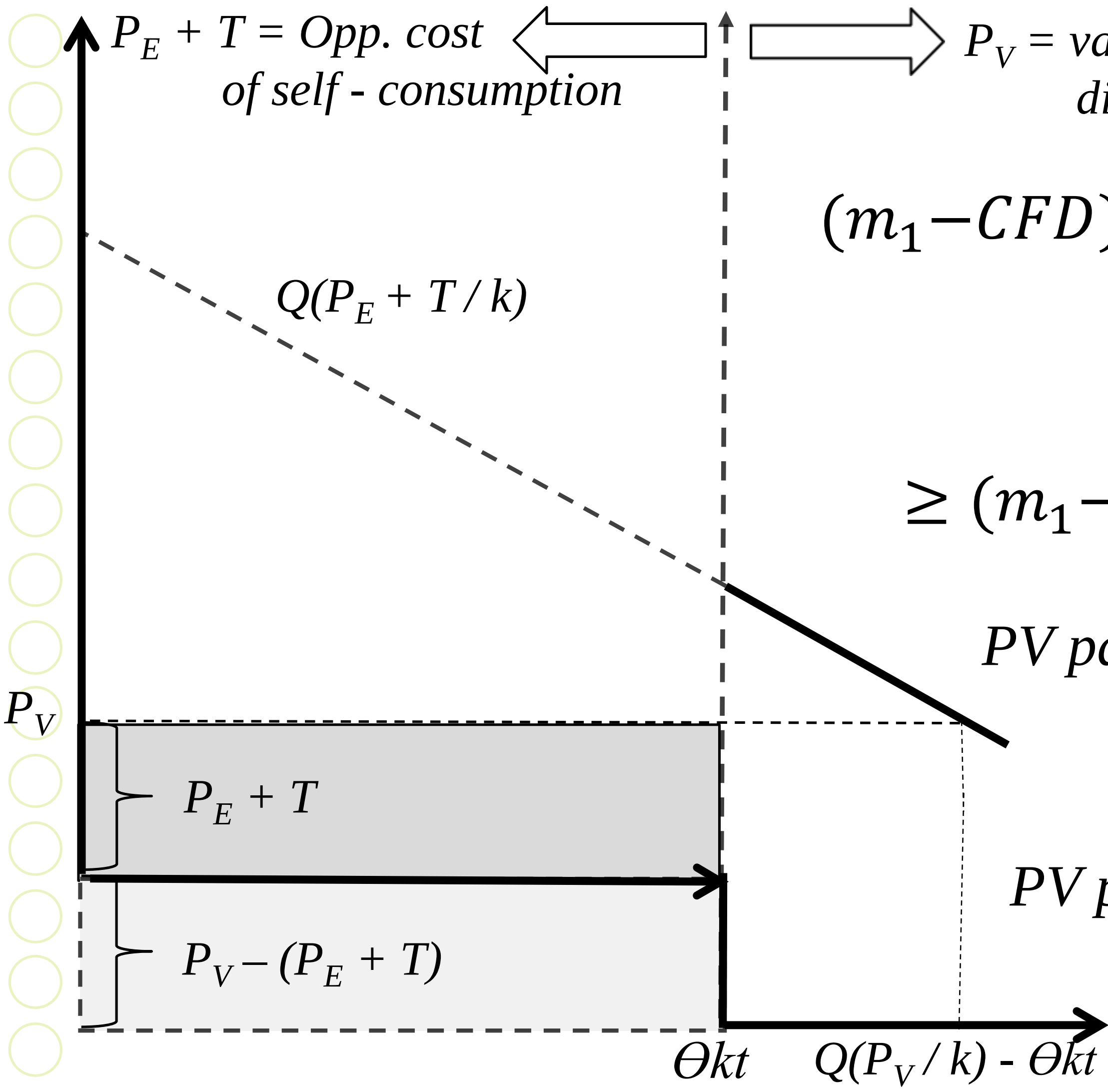
PV Panel Installation Decision by a T_1 User : *Benefit - Cost Analysis of HOM by the Distro*



P_V = variable component of distribution rate

$$(m_1 - CFD) + [Q(P_V/k) - \theta kt]\ (P_V - CVD)$$

$$+\theta kt\ [P_E + T]$$

$$\geq (m_1 - CFD) + Q(P_V/k)(P_V - CVD)$$

PV panel will be profitable for Distro iff

$$\boxed{(P_E + T) - (P_V - CVD) \geq 0}$$

PV panel will be profitable for user iff

$$\boxed{[P_V - (P_E + T)]\theta kt - C \geq 0}$$

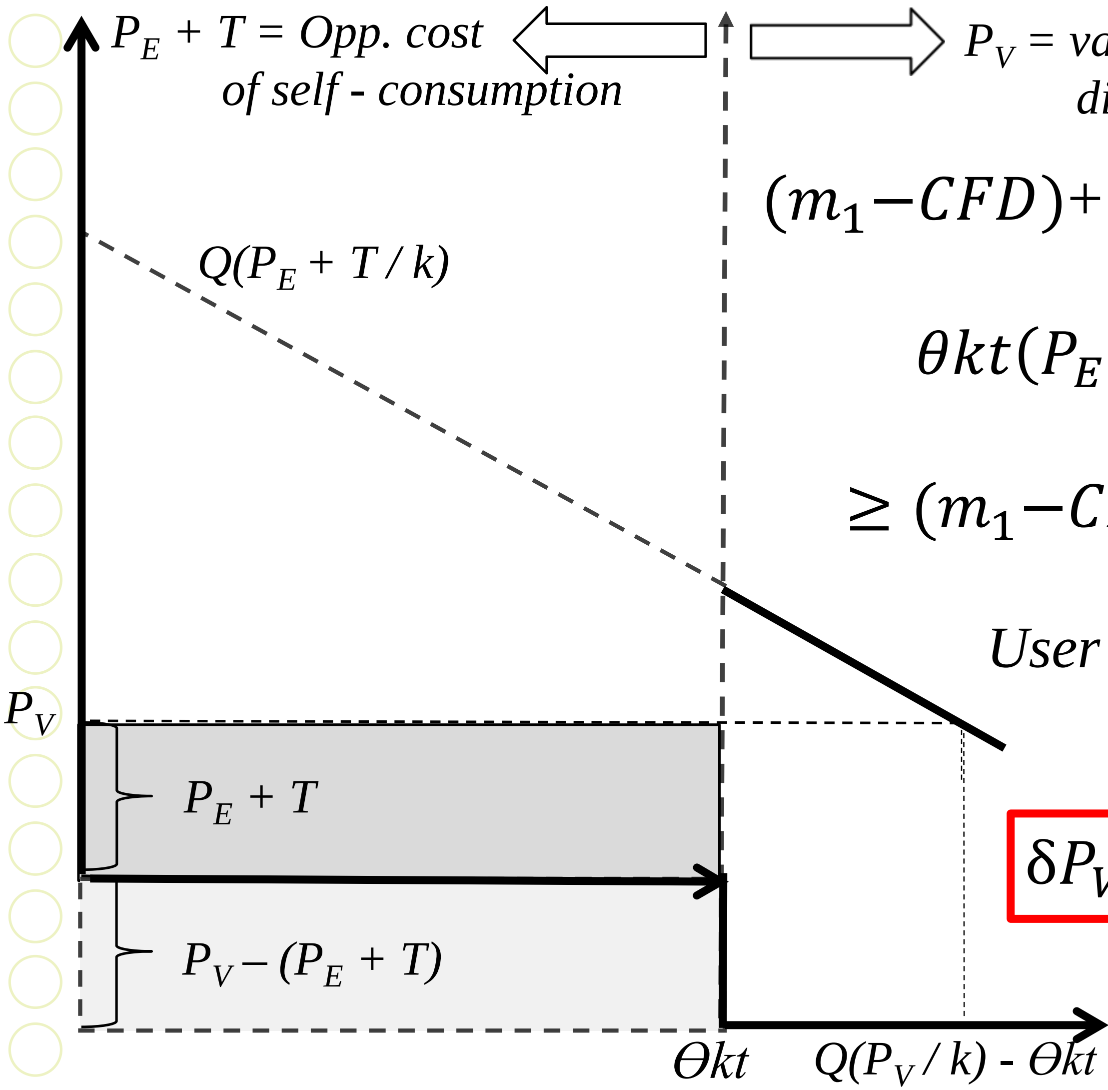
PV Panel Installation Decision by the Distro : *More incentives to benefit from PV panel installation if...*

$$(P_E + T) - (P_V - CVD) \geq 0$$

Savings in wholesale costs: What the Distro does not have to spend in wholesale electricity purchases − *Per unit foregone variable profit: What the distro foregoes per unit of self consumed energy* ≥ 0

- For Distro to be ok with PV panels, P_V has to be low (fixed charge m high)
- Distribution costs have to be recovered mostly through fixed charges (*sunk* or irrelevant for users) rather than varible charges (*avoidable* for users)
- Problem with fixed charges → 1) Sunk for users, 2) Do not reflect cost reductions due to DG, 3) May encourage disconnection, 4) Too high LI families

How to reconcile both positions: *A Coasian approach → Distro owns the PV panel*



$$(m_1 - CFD) + [Q(P_V/k) - \theta kt]\ (P_V - CVD) - C$$

$$\theta kt(P_E + T) + \ \theta kt\ (1 - \delta)P_V$$

$$\geq (m_1 - CFD) + Q(P_V/k)(P_V - CVD)$$

User better off, Distro better off too iff:

$$\boxed{\delta P_V \theta kt \leq [(P_E + T) + CVD]\theta kt - C}$$

PV Panel Installation Decision by the Distro: Problem » *Potential Rents in Passthrough*

$$\pi_{w/panel} = (m_1 - CFD) + [Q(P_V/k) - \theta kt]\ (P_V - CVD) - C$$

$$+\,\theta kt\,(P_E + T) + \ \theta kt\ \ (1-\delta)P_V$$

$$a)\ If\ \ \delta P_V \theta kt = [(P_E + T) + CVD]\,\theta kt - C \quad then:$$

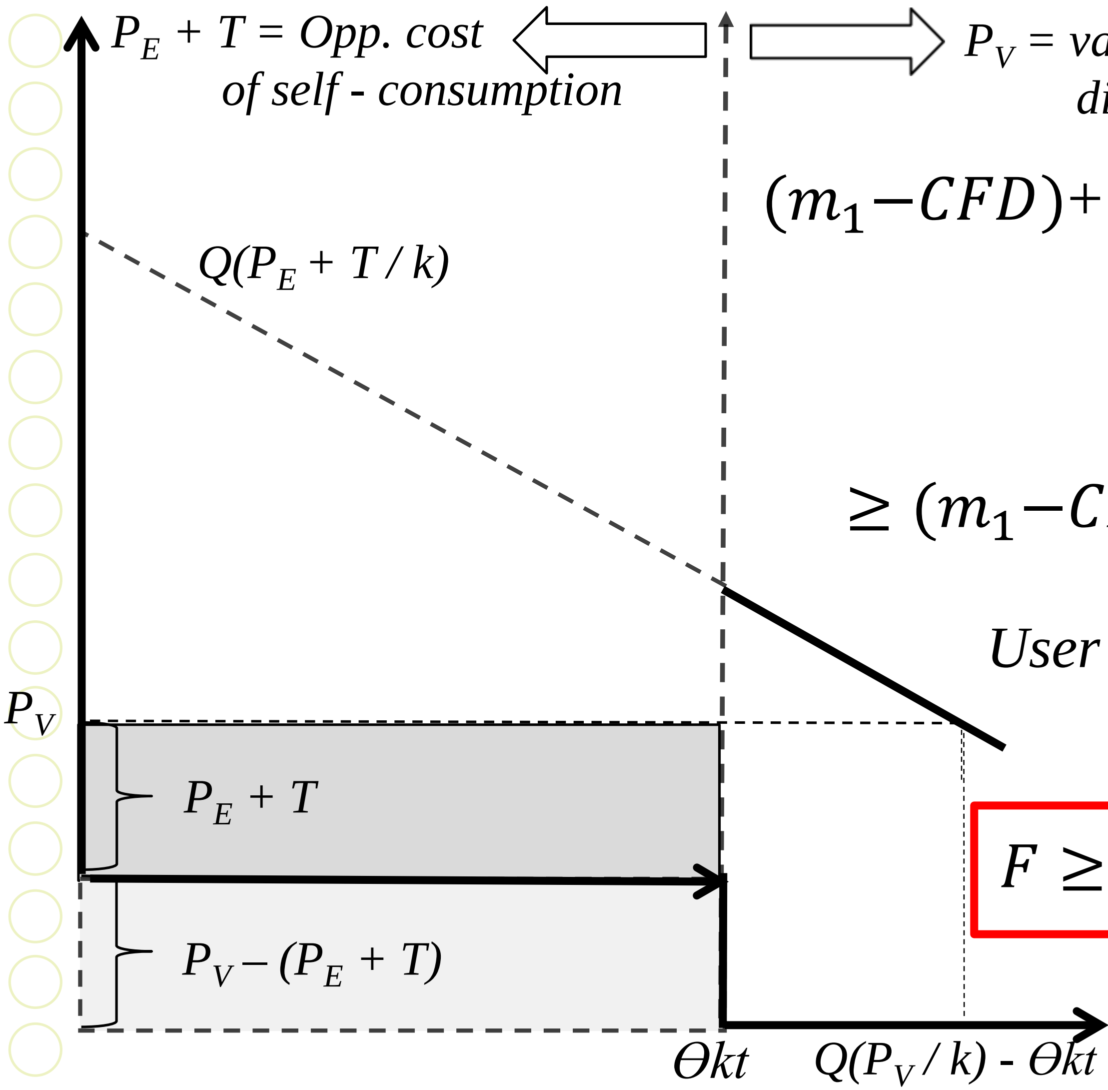
$$\pi_{w/panel} = (m_1 - CFD) + Q(P_V/k)\ (P_V - CVD) \quad it's\ ok$$

$$b)\ If\ \ \delta P_V \theta kt < [(P_E + T) + CVD]\,\theta kt - C \quad then:$$

$$\pi_{w/panel} > (m_1 - CFD) + Q(P_V/k)\ (P_V - CVD)\ \ it's\ \boldsymbol{NOT}\ ok$$

Regulator has to make sure passthrough price is competitive!!

How to reconcile both positions: *A Coasian approach → Distro leases the PV panel*



$$(m_1 - CFD) + [Q(P_V/k) - \theta kt]\ (P_V - CVD) - C$$

$$\theta kt(P_E + T) + F$$

$$\geq (m_1 - CFD) + Q(P_V/k)(P_V - CVD)$$

User better off, Distro better off too iff:

$$\boxed{F \geq C + \theta kt\,[(P_V - CVD) - (P_E + T)]}$$

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Further Research (2nd part of the paper...)

- Privately determined # of PV users socially optimal? NO....
- Users do not internalize either (short and long term) network cost reductions due to PV DG or externalities (*i.e.* fossil fuel pollution)
- Socially optimal # of PV users $\rightarrow$ min (Private + Social Cost)
- Can centralized socially optimal solution be achieved through decentralized negotiations? Maybe...Coase theorem?
- Some degree of vertical integration + regulation of passthrough of wholesale prices may be necessary
- # of PV users under VI ~ socially optimal? Don't know
- How much regulation is necessary?

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Concluding Remarks

- Users will install PV panels whenever variable (*avoidable*) charges are high → problem: more incentives in T_1 – R categories than in T_2 or T_3 that have more financial strength
- Distros will benefit from PV installation whenever variable (*avoidable*) charges are low and fixed (sunk) charges are high
- This contradiction may be mitigated by adopting a Coasian approach to externalities → Assign property rights of PV panels to Distros and let both parties reach a mutually beneficial agreement → Regulator has to monitor passthrough of δP_V

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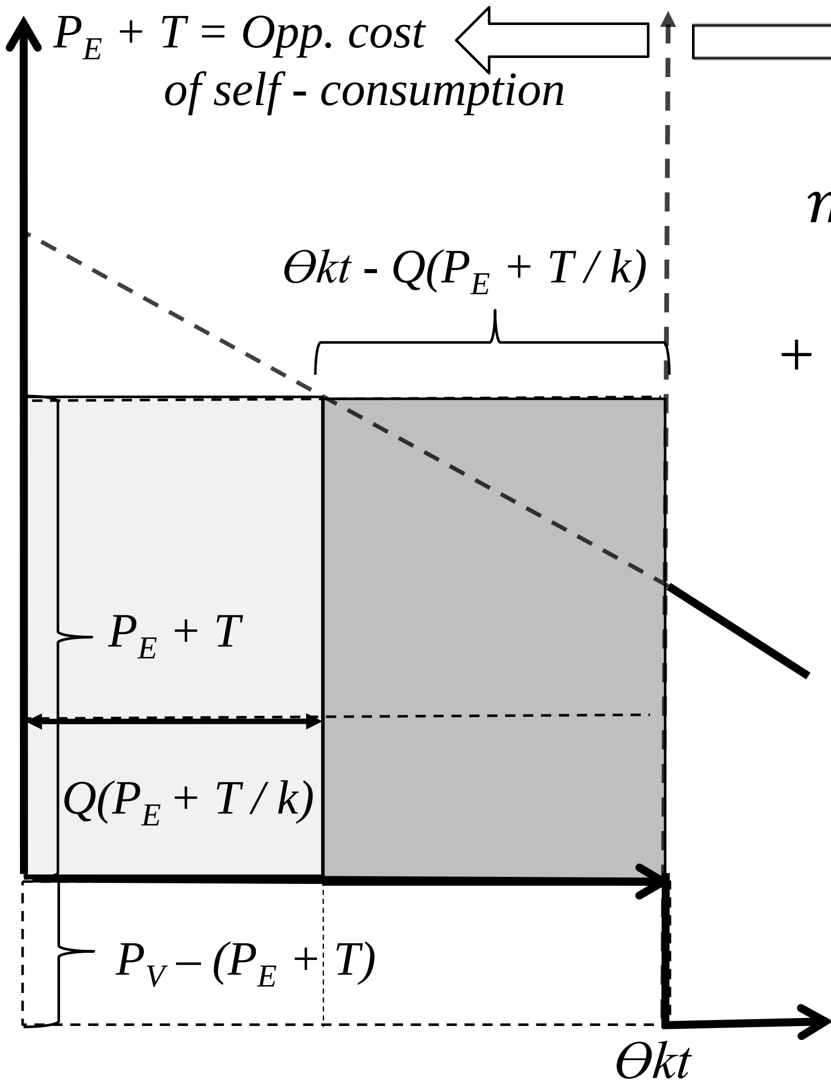
Back – up Slides

PV Panel Installation Decision by a T_1 User : *Host Ownership Model (HOM)*



P_V = variable component of distribution rate

$$m_1 - (P_E + T)\,[\theta kt - Q(P_E + T/k)] + C$$

$$+ (P_E + T)Q(P_E + T/k) \leq m_1 + Q(P_V/k)P_V$$

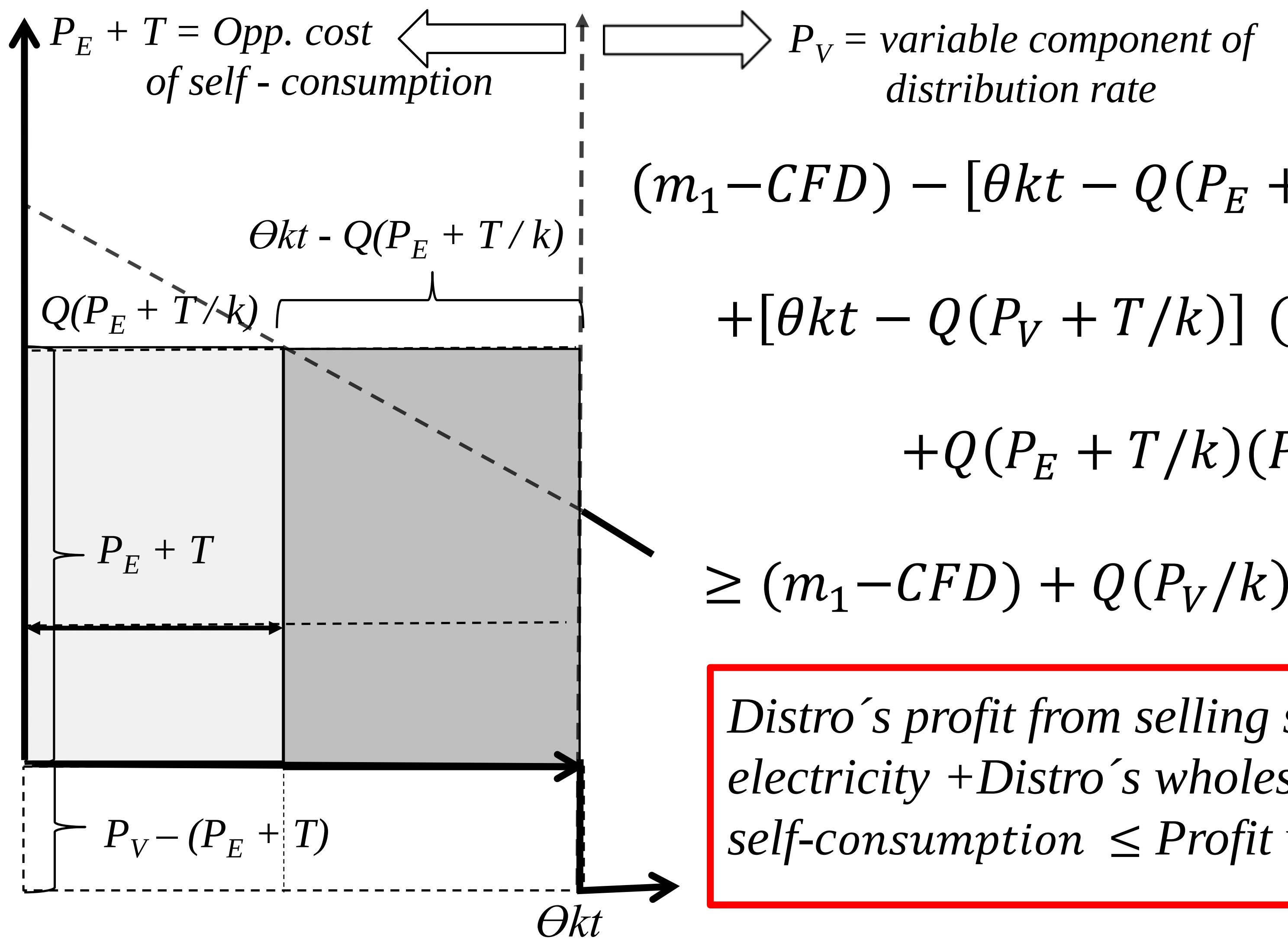
T_1 user decides to install PV panel iff

$$C - (P_E + T)\,[\theta kt - Q(P_E + T/k)] +$$

$$+ (P_E + T)Q(P_E + T/k) \leq Q(P_V/k)P_V$$

C – Sales to Distro + Opp. cost of self consumption ≤ Cost w/o PV panel

PV Panel Installation Decision by a T_1 User : *Benefit – Cost Analysis by the Distro of HOM*



$$(m_1 - CFD) - [\theta kt - Q(P_E + T/k)]\,(P_E + T)$$

$$+[\theta kt - Q(P_V + T/k)]\,(P_V - CVD) +$$

$$+Q(P_E + T/k)(P_E + T)$$

$$\geq (m_1 - CFD) + Q(P_V/k)(P_V - CVD)$$

Distro´s profit from selling self-generated electricity +Distro´s wholesale savings from self-consumption ≤ Profit w/o PV panel

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Final Tariffs by User Type: T1, T2, T3 and GU

- Small Demands $0 \leq T_1 - R - G \leq 10$ KW (load not metered)

$$T_1 = CFD_{R/G} + \left[P_E(1 + l_E) + \frac{P_K(1+l_K) * FCE_1}{730 * FC_{R/G}} + T + CVD_{R/G} \right] Q_1 \; (P_V/K)$$

- Medium Demands: $10 \text{ KW} \leq T_2 \leq 50$ KW (load metered)

$$T_2 = CFD_2 + P_K(1 + l_K)FCE_2 + [P_E(1 + l_E) + T + CVD_2] \, Q_2 \; (P_V/K)$$

- Medium – Large Demands T_3: 50 KW – 300 KW and > 300KW

$$T_3 = CFD_3 + P_K(1 + l_K)FCE_3 + [P_E(1 + l_E) + T] \, Q_3 \; (P_V/K)$$

- $(T_2 + T_3)$ toll + Large Demands (GU's) (load metered, TOU pricing)
- $$T_{2/3} = CFD_{2/3} + P_K l_K FCE_{2/3} + [P_E l_E + T] \, Q_3 \; (P_V/K)$$