3.61

Compressed air car: 68mph 125mi(max)
$2 to fill
V = 340 Liters → .34m³
P = 4350psi → $4350\,psi\left(\frac{6894.75\,Pa}{1\,psi}\right) = 29992\,kPa$

a) Max work of air tank?
Miles per gallon of gas equivalent (1 gal gas = 130MJ energy)

$$W = \int P\,dV \Rightarrow nR\int_{V_i}^{V_f}\frac{T}{V}\,dV \Rightarrow P_iV_i\int\frac{1}{V} = P_iV_i\ln\frac{V_f}{V_i}$$

$PV = nRT$ (R constant) | $nRT$ constant
$PV = nT$ | $P_iV_i = nRT$

assume ideal gas $\frac{V_f}{V_i} = \frac{P_i}{P_f}$
assume $P_{atm} = 100\,kPa = P_f$

$$29992\,kPa\,(.34m^3)\ln\left(\frac{29992\,kPa}{100}\right)$$
$$= 5.87J \rightarrow \boxed{58.16\,MJ\ max\ work}$$

$$58.16MJ\ air\left(\frac{gal}{130MJ\ gas}\right) = \boxed{.447\,gal}$$

$$125\,miles\ range\left(\frac{1}{.447\,gal\ gas}\right) = \boxed{279.64\ \frac{mile}{gal\ gas}\ equivalent}$$

b) Power of compressor?
Cost of electricity?

$C_{V\,air} = \frac{5R}{2}$ $C_{P\,air} = \frac{7R}{2}$
$= .718\frac{kJ}{kg\,K}$ $= 1.005\frac{kJ}{kg\,K}$

fill 340L to 4350psi in 5min

$\frac{1J}{s} = 1\,Watt$

.34m³ @ 4350psi

$K = \frac{C_P}{C_V} = 1.4$ $MW_{air} = 28.97\frac{kg}{kmol}$ $\rho_{air} = 1.2\frac{kg}{m^3}$

$\dot{m}_{air} = .34\,m^3 \left(\frac{1.2\,kg}{m^3}\right) = \frac{.41\,kg}{5\,min} = .41\,kg\left(\frac{1}{5\,min}\right)\left(\frac{1\,min}{60\,sec}\right)$

$= .00141\,\frac{kg}{s}$

$Power = \dot{m}(c_p)\,T\left(\frac{P_2}{P_1}\right)^{\frac{K-1}{K}} - 1$

$= .00141\,\frac{kg}{s}\left(1.005\,\frac{kJ}{kg\,K}\right)(20+273K)\left(\frac{29992\,kPa}{100\,kPa}\right)^{\frac{1.4-1}{1.4}} - 1$

$= .41\,(5.10) - 1$

$= 1.09\,\frac{J}{s}\left(\frac{60\,sec}{min}\right)\left(\frac{60\,min}{hr}\right)$

$= 3927.6\,kWh$

$\frac{\$2}{3927.6} = \boxed{\$.0005/kWh}$